Developmental Biology

Volume 217, Issue 2, 15 January 2000, Pages 375-385

Regular Article

Presence and Roles of Calcium Gradients along the Dorsal-Ventral Axis in Drosophila Embryos

Robbert Créton [1] … Lionel F. Jaffe

Show more

https://doi.org/10.1006/dbio.1999.9542

Abstract

Dorsal-ventral specification of the Drosophila embryo is mediated by signaling pathways which have been very well described in genetic terms. However, little is known about the physiology of Drosophila development. By imaging patterns of free cytosolic calcium in Drosophila embryos, we found that several calcium gradients are generated along the dorsal-ventral axis. The most pronounced gradient is formed during stage 5, in which calcium levels are high dorsally. Manipulation of the stage 5 calcium gradient affects specification of the amnioserosa, the dorsal-most region of the embryo. We further show that this calcium gradient is inhibited in *pipe, Toll,* and *dorsal* mutants, but is unaltered in *decapentaplegic (dpp)* or *punt* mutants, suggesting that the stage 5 calcium gradient is formed by a suppression of ventral calcium concentrations. We conclude that calcium plays a role in specification of the dorsal embryonic region.

Keywords

pattern formation; embryonic development; signaling pathways; dorsoventral axis; [Ca^{2+}]; TGF-β; aequorin; imaging photon detector

References

REFERENCES

1 D.G. Allen, J.R. Blinks, F.R. Prendergast
Aequorin luminescence: Relation of light emission to calcium concentration
Science, 196 (1977), pp. 996-998

2 K.V. Anderson, G. Jurgens, C. Nusslein-Volhard
Establishment of dorsal-ventral polarity in the Drosophila embryo: Genetic studies on the role of the Toll gene product
Cell, 42 (1985), pp. 779-789
Article PDF (7MB)

3 K.V. Anderson
Pinning down positional information: Dorsal-Ventral polarity in the Drosophila embryo
Cell, 95 (1998), pp. 439-442

Article PDF (105KB)

4 H.L. Ashe, M. Levine
Local inhibition and long-range enhancement of Dpp signal transduction by Sog
Nature, 398 (1999), pp. 427-431

5 K. Beckingham
Calcium regulation of Drosophila development
Adv. Sec. Mess. Phosph. Res., 30 (1995), pp. 359-394

6 M.P. Belvin, K.V. Anderson
A conserved signaling pathway: the Drosophila toll-dorsal pathway
Annu. Rev. Cell Dev. Biol., 12 (1996), pp. 393-416

7 R. Créton, J.A. Kreiling, L.F. Jaffe
Calcium imaging with chemiluminescence
Microsc. Res. Tech., 46 (1999), pp. 390-397

8 E.L. Ferguson, K.V. Anderson
Decapentaplegic acts as a morphogen to organize dorsal-ventral pattern in the Drosophila embryo
Cell, 71 (1992), pp. 451-461
Article PDF (6MB)

9 E.L. Ferguson, K.V. Anderson
Localized enhancement and repression of the activity of the TFG-β family member, decapentaplegic, is necessary for dorsal-ventral pattern formation in the Drosophila embryo
Development, 114 (1992), pp. 583-597

10 E.L. Ferguson
Conservation of dorsal-ventral patterning in arthropods and chordates
Curr. Opin. Genet. Dev., 6 (1996), pp. 424-431
Article PDF (849KB)

11 D.D. Ginty
Calcium regulation of gene expression: Isn't that spatial?
Neuron, 18 (1997), pp. 183-186
Article PDF (480KB)

12 G.E. Hardingham, F.H. Cruzalegui, S. Chawla, H. Bading
Mechanisms controlling gene expression by nuclear calcium signals
Cell Calcium, 23 (1998), pp. 131-134
Article PDF (918KB)

13 S.A. Holley, E.L. Ferguson
Fish are like flies are like frogs: Conservation of dorsal-ventral patterning mechanisms
Bioessays, 19 (1997), pp. 281-284

14 J.D. Huang, D.H. Schwyter, J.M. Shirokawa, A.J. Courey
The interplay between multiple enhancer and silencer elements defines the pattern of decapentaplegic expression
Genes Dev., 7 (1993), pp. 694-704

15 Y. Jacob, S. Sather, J.R. Martin, R. Ollo
Analysis of Kruppel control elements reveals that localized expression results from the interaction of multiple subelements
Proc. Natl. Acad, Sci. USA, 88 (1991), pp. 5912-5916

16 L.F. Jaffe
Ventral activation process in insect oocytes
Nature, 321 (1986), p. 386

17 K. Kubota, F.J. Keith, N.J. Gay
Relocalization of Drosophila dorsal protein can be induced by a rise in cytoplasmic calcium concentration and the expression of constitutively active but not wild-type Toll receptors
Biochem. J., 296 (1993), pp. 497-503

18 K. Kubota, N.J. Gay
Calcium destablizes Drosophila cactus protein and dephosphorylates the dorsal transcription factor
Biochem. Biophys. Res. Commun., 214 (1995), pp. 1191-1196
Article PDF (329KB)

19 A. Letsou, K. Arora, J.L. Wrana, K. Simin, V. Twombly, J. Jamal, K. Staehling-Hampton, F.M. Hoffmann, W.M. Gelbart, J. Massague, M.B. O'Connor
Drosophila Dpp signalling is mediated by the punt gene product: A dual ligand-binding type II receptor of the TGFb receptor family
Cell, 80 (1995), pp. 899-908
Article PDF (4MB)

20 G. Marques, M. Musacchio, M.J. Shimell, K. Wunnenberg-Stapleton, K.W. Cho, M.B. O'Connor
Production of a Dpp activity gradient in the early Drosophila embryo through the opposing actions of the SOG and TLD proteins
Cell, 91 (1997), pp. 417-426
Article PDF (296KB)

21 J. Massagué, L. Attisano, J.L. Wrana
The TGF-β family and its composite receptors
Trends Cell Biol., 4 (1994), pp. 172-178
Article PDF (852KB)

22 J. Massagué
TGF-beta signal transduction
Annu Rev. Biochem., 67 (1998), pp. 753-791

23 D. Morisato, K.V. Anderson
Signaling pathways that establish the dorsal-ventral pattern of the Drosophila embryo
Annu. Rev. Genet., 29 (1995), pp. 371-399

24 M.C. Mullins
Holy tolloido: Tolloid cleaves SOG/Chordin to free DPP/BMPs
Trends Genet., 14 (1998), pp. 127-129
Article PDF (146KB)

25 H.B. Nelson, R.G. Heiman, C. Bolduc, G.E. Kovalick, P. Whitley, M. Stern, K. Beckingham
Calmodulin point mutations affect Drosophila development and behavior
Genetics, 147 (1997), pp. 1783-1798

26 R.W. Padgett, D. St Johnston, W.M. Gelbart
A transcript from a Drosophila pattern gene predicts a protein homologous to the transforming growth factor-β family
Nature, 325 (1987), pp. 81-84

27 R. Pethig, M. Kuhn, R. Payne, E. Adler, T.H. Chen, L.F. Jaffe
On the dissociation constants of BAPTA-type calcium buffers
Cell Calcium, 10 (1989), pp. 491-498
Article PDF (718KB)

28 L.A. Raftery, D.J. Sutherland
TGF-beta family signal transduction in Drosophila development: From Mad to Smads
Dev. Biol., 210 (1999), pp. 251-268
Article PDF (649KB)

29 R. Ray, K. Arora, C. Nusslein-Volhard, W.M. Gelbart
The control of cell fate along the dorsal-ventral axis of the Drosophila embryo
Development, 113 (1991), pp. 35-54

30 S. Roth, D. Stein, C. Nusslein-Volhard
A gradient of nuclear localization of the dorsal protein determines dorsoventral pattern in the Drosophila embryo
Cell, 59 (1989), pp. 1189-1202
Article PDF (4MB)

31 F. Ruberte, T. Marty, D. Nellen, M. Affolter, K. Basler

An absolute requirement for both the type II and type I receptors, punt and thick veins, for Dpp signalling in vivo
Cell, 80 (1995), pp. 889-897
Article PDF (7MB)

32 C.A. Rushlow, K. Han, J.L. Manley, M. Levine
The graded distribution of the dorsal morphogen is initiated by selective nuclear transport in Drosophila
Cell, 59 (1989), pp. 1165-1177
Article PDF (9MB)

33 J. Sen, J.S. Goltz, L. Stevens, D. Stein
Spatially restricted expression of pipe in the Drosophila egg chamber defines embryonic dorsal-ventral polarity
Cell, 95 (1998), pp. 471-481
Article PDF (735KB)

34 O. Shimomura, S. Inouye
Titration of recombinant aequorin with calcium chloride *Biochem*
Biophys. Res. Commun., 221 (1996), pp. 77-81
Article PDF (52KB)

35 J.E. Speksnijder, A.L. Miller, M.H. Weisenseel, T.H. Chen, L.F. Jaffe
Calcium buffer injections block fucoid egg development by facilitating calcium diffusion
Proc. Natl. Acad. Sci. USA, 86 (1989), pp. 6607-6611

36 R. Steward
Relocalization of the dorsal protein from the cytoplasm to the nucleus correlates with its function
Cell, 59 (1989), pp. 1179-1188
Article PDF (10MB)

37 S.A. Stricker, M. Whitaker
Confocal laser scanning microscopy of calcium dynamics in living cells
Microsc. Res. Tech., 46 (1999), pp. 356-369

38 P. Ten Dijke, K. Miyazono, C.H. Heldin
Signaling via hetero-oligomeric complexes of type I and type II serine/threonine kinase receptors
Curr. Opin. Cell Biol., 8 (1996), pp. 139-145

39 N.A. Wall, B.L.M. Hogan
TGF-β related genes in development
Curr. Opin. Gen. Dev., 4 (1994), pp. 517-522
Article PDF (2MB)

40 K.A. Wharton, R.P. Ray, W.M. Gelbart
An activity gradient of decapentaplegic is necessary for the specification of dorsal pattern elements in the Drosophila embryo
Development, 117 (1993), pp. 807-822

41 E. Wieschaus, C. Nusslein-Volhard
Looking at embryos
D.B. Roberts (Ed.), Drosophila a Practical Approach, IRL press, Washington (1986), pp. 199-227

42 C.M. Zimmerman, M.S. Kariapper, L.S. Mathews
Smad proteins physically interact with calmodulin
J. Biol. Chem., 273 (1998), pp. 677-680

1 Present address: Brown University School of Medicine, Department of Obstetrics and Gynecology, Women and Infants Hospital, 101 Dudley Street, Providence, RI 02905.